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The Digital Transformation of the Global Green Bonds Market:

New-Fashioned International Standards for a New Generation of Financial Instruments

Dr. Georgios Pavlidis[1]

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Abstract: *Post-pandemic economic recovery plans favour sustainable growth and resort to the issuance of sustainable bonds, which is expected to increase exponentially in the following years. The challenge will be to build a credible, efficient, and transparent green bond market to drive the global green transition. Digitalization and standardization have the potential to accelerate this process in the post-COVID era, as they enhance transparency and verifiability in the green bond markets. Factors such as the multicity, complexity, and lack of comparability of environmental, social, and governance (ESG) standards and objectives can be addressed through the standardization of the ESG indicators and the methodology for impact reporting. In addition to this, digitalization can increase the reliability of sustainability reporting and help attract responsible investors who increasingly favour sustainable projects and invest their funds accordingly. The next big challenge will be creating a new breed of fully digitalised green bonds, using blockchain from its issuance until the reporting phase, which in the case of green bonds covers both the use of proceeds and the proof of impact. Combining digitalization with international standardization will further allow the scaling of green bond markets to meet the growing demand.*

[1] Jean Monnet Chair, Associate Professor of International and EU Law, School of Law, Neapolis University Pafos, Cyprus; email: g.pavlidis@nup.ac.cy

I. Sustainable Finance and Digitalization

Over the last ten years, there has been a clear trend in financial markets favouring environmental, social, and governance (ESG) investing. The trend was first manifest in equity markets but soon spread to other asset classes, especially fixed income instruments.[2] International bond markets have a market capitalisation of USD 128.3tn,[3] consisting of corporate bonds (USD 40.9tn) and SSA bonds, namely, supranational, sovereign, sub-sovereign, and agency bonds (USD 87.5tn). Bond markets currently attract more investments than equity securities listed on stock exchanges, especially from institutional investors. As the COVID-19 pandemic hit the global economy, ESG considerations were side-lined, at least in the initial stages of the crisis. The objectives of sustainable development, protection of the environment, and climate change mitigation are usually the first to be put on hold in times of crisis.[4] Nevertheless, the global market for sustainable debt has made an impressive comeback reaching a record USD 732bn in 2020. This was due to the design of post-pandemic economic recovery plans, all of which favour sustainable growth and resort to the issuance of sustainable bonds.[5] The European Union (EU), with its ambitious Recovery Plan for Europe and the EU Green Deal,[6] is a prime example of this process, which can reshape the European economic and financial landscape. In this context, the issuance of green bonds, namely, fixed-income debt instruments earmarked to finance green projects, is expected to increase exponentially in

[2] Georg Inderst and Fiona Stewart, *Incorporating Environmental, Social and Governance (ESG) Factors into Fixed Income Investment* (World Bank 2018).

[3] According to the estimates of the International Capital Markets Association (ICMA), based on Bloomberg Data, this consists of $87.5 trillion in SSA bonds (Sovereigns, Supranational and Agencies) and $40.9 trillion in corporate bonds. See: https://www.icmagroup.org/Regulatory-Policy-and-Market-Practice/Secondary-Markets/bond-market-size/ accessed 16 July 2021.

[4] Charlotte Burns, Peter Eckersley and Paul Tobin, 'EU Environmental Policy in Times of Crisis' (2020) 27(1) Journal of European Public Policy 1. See also: Yves Steinebach and Christoph Knill, 'Still an Entrepreneur? The Changing Role of the European Commission in EU Environmental Policymaking' (2017) 24(3) Journal of European Public Policy 246.

[5] Bloomberg, 'Social Bonds Propel ESG Issuance to Record $732 Billion in 2020' (Bloomberg Green, 11 January 2021) <https://www.bloomberg.com/news/articles/2021-01-11/social-bonds-propel-esg-issuance-to-record-732-billion-in-2020> accessed 16 July 2021; Financial Times, 'Green bonds will be war bonds for the post-Covid generation' (FT Adviser, 17 March 2021) <https://www.ftadviser.com/opinion/2021/03/17/green-bonds-will-be-war-bonds-for-the-post-covid-generation/> accessed 16 July 2021.

[6] In summer 2020, the European Council adopted the EU recovery plan and multiannual financial framework (MFF) for 2021-2027, with the objective to "ensure that the next MFF as a whole contributes to the implementation of the Paris Agreement"; see Conclusions of the Special meeting of the European Council (17-21 July 2020) 14. The EU intends to borrow €750 bn under NextGenerationEU, 30% of which will be raised through green bonds.

the following years. The challenge will be to build a credible, efficient, and transparent green bond market to drive the global green transition.

Standardization and digitalization can increase the credibility, efficiency, and transparency in the green bond markets, from issuance and initial distribution of bonds to reporting. Regarding the latter, the credibility of sustainable and green finance is greatly dependent on the quality of data, not only financial but mainly extra-financial, such as data on the "sustainable performance" and "green performance" of a project. International and regional standards stress the need for such meaningful and material data;[7] nevertheless, the variety of green initiatives is steadily increasing and now includes projects in renewable energy, energy efficiency, climate adaptation, payments for ecosystem services, and biodiversity offsetting, which will bring a corresponding increase in the volume and complexity of data to be reported.

To deal with this new complexity, sound rules and standards must be developed to ensure transparency and a level playing field.[8] Moreover, digitalization needs to be mobilised to further increase transparency and efficiency. For example, in the field of extra-financial reporting for green bonds, digitalization can facilitate and accelerate the compilation, analysis, and reporting of "green performance" data from multiple green projects. Data collected through sensors and the internet of things (IoT) could thus be analysed by artificial intelligence (AI) algorithms, recorded on the blockchain, and ultimately delivered to the markets promptly, accurately, and with minimum cost. Thus, we argue that the issuers and the investors can reap similar benefits from digital innovation in the entire lifecycle of a green bond, a potential that will sway the markets into embracing such innovation and implement it at scale.

II. The Market for Green Bonds

[7] UNEP Finance /United Nations Global Compact, 'Driving meaningful data: financial materiality, sustainability performance and sustainability outcomes' (September 2020) 3.
[8] Alan Morrison and Lucy White, 'Level Playing Fields in International Financial Regulation' (2009) 64(3) The Journal of Finance 1099; Fernando Restoy, 'Fintech Regulation: How to Achieve a Level Playing Field' (Bank for International Settlements, Financial Stability Institute 2021) 9.

Green bonds are increasingly popular debt instruments, which may be issued by financial or non-financial private entities, alongside public entities (supranational, sovereign, sub-sovereign, and agency issuers).[9] The feature that distinguishes green bonds from other fixed-income instruments is the "green" character, namely, that they are asset-linked and earmarked to finance environmentally friendly projects.[10] Green bonds are used to finance an increasingly wider range of sustainable and transition investments, while new types of instruments have emerged that deviate from the use-of-proceeds model. For example, KPI-linked bonds (key performance indicators) or SDG-linked bonds (Sustainable Development Goals) do not finance a specific green project, but their financial characteristics depend on the issuer's progress towards sustainability targets that are monitored and externally verified.[11]

Issuance in green bond markets was growing steadily in the years preceding the COVID19 crisis, as part of a general trend favouring ESG investing. In 2019, 500 private and public issuers opted for the issuance of green bonds globally, launching 1800 financial deals totalling USD 259bn.[12] The trend was manifest both in developed and emerging markets, with the latter entering the game and attracting USD 52bn in new issuances, which represented a substantial increase of 21% compared to 2018.[13] As a result, optimism was prevalent, ESG investing was projected to rise further, and most analysts were expecting 2020 to be a record year for green bonds.

The COVID19 crisis, which erupted in early 2020, has been a breaking point. It negatively affected market conditions, dampened investment prospects in the short-term

[9] Heike Reichelt and Colleen Keenan, 'The Green Bond Market: 10 years later and looking ahead' in World Bank, *Green Bonds* (World Bank 2017) 1; World Bank*, What are Green Bonds?* (World Bank, Public-Private Infrastructure Advisory Facility 2015) 7.

[10] Annica Cochu and others, 'Study on the potential of green bond finance for resource-efficient investments' (Study prepared for the European Commission 2016) 22. For a different security design, see: Dion Bongaerts and Dirk Schoenmaker, 'Green certificates: a better version of green bonds' (Bruegel Policy Contribution 2020)

[11] International Capital Markets Association, 'Sustainability-Linked Bond Principles: Voluntary Process Guidelines' (ICMA 2020); PIMCO, 'Best Practice Guidance for Sustainable Bond Issuance' (PIMCO 2020); Dhara Ranasinghe, 'Sustainability-linked bond market to swell up to $150 billion', *Reuters* (22 March 2021).

[12] Climate Bonds Initiative, 'Green Bonds Global State of the Market 2019' (CBI 2019).

[13] International Finance Corporation, 'Emerging Market Green Bonds Report 2019: Momentum Builds as Nascent Markets Grow' (World Bank/IFC 2020) 5.

while creating long-term uncertainty.[14] Unsurprisingly, this has affected the issuance of green bonds globally, which has dropped to half of the previous year's levels. However, the initial shock did not have a universal affect; developed markets were hit less hard than emerging markets, and SSA issuers were better off than private issuers.[15] As the crisis unfolded and sluggishly became more manageable, markets began turning their interest to the post-COVID economic recovery. In this context, green bonds are expected to be a preferred option for long-term investing by responsible investors.[16] From their part, corporate and SSA issuers are expected to resort to green bond issuance to finance sustainable projects, foster their ESG resilience, and position themselves better for the global transition towards a greener economy. Supported by these factors and as the world economy kick-starts, the issuance of green bonds has already started to recuperate.[17]

Digitalization and standardization have the potential to accelerate this process in the post-COVID era, as they significantly enhance transparency and verifiability in the green bond markets. Sustainable development,[18] as embodied in the UN SDGs and the UN Agenda 2030,[19] presupposes transparency and verifiability of information. ESG responsible businesses already employ sustainability indicators and integrate them into their business processes and extra-financial reporting cycles;[20] they do so not only to

[14] Organization for Economic Co-operation and Development, 'Global financial markets policy responses to COVID-19' (OECD 2020) 4; International Capital Markets Association, 'COVID-19: The Impact on Capital Markets and the Response' (ICMA Quarterly Report No 57 2020) 4.
[15] Climate Bonds Initiative, 'Global State of the Market for 2020, Interim Report' (CBI 2020) 4.
[16] There is no clear consensus on the the green bond pricing and existence of green bond premiums; Stefen MacAskill and others, 'Is there a green premium in the green bond market? Systematic literature review revealing premium determinants' (2021) 280 Journal of Cleaner Production; see also the 2016-2020 report on 'Green Bond Pricing in Primary Market' by the Climate Bonds Initiative.
[17] Ben Caldecott, 'Defining transition finance and embedding it in the post-Covid-19 recovery' (2021) Journal of Sustainable Finance & Investment [Latest Articles] DOI: 10.1080/20430795.2020.1813478; Lukasz Krebel and others, 'Building a Green Stimulus for Covid-19: A Recovery Plan for a Greener, Fairer Future' (New Economics Foundation 2020) 25; Genevieve Pons and others, 'Greener After: A Green Recovery for a Post-COVID-19 World' (2020) 40(1) SAIS Review of International Affairs 69.
[18] Aarti Gupta, Ingrid Boas and Peter Oosterveer, 'Transparency in global sustainability governance: to what effect?' (2020) 22:1 Journal of Environmental Policy & Planning 84; Aarti Gupta and Michael Mason (eds.), *Transparency in global environmental governance: Critical perspectives* (MIT Press 2014); Michael Mason, 'Transparency for whom? Information disclosure and power in global environmental governance' (2008) 8(2) Global Environmental Politics 8, etc.
[19] See United Nations, 'Transforming our World: The 2030 Agenda for Sustainable Development' (UN 2015); United Nations Development Programme, 'Sustainable Development Goals' (UNDP Booklet 2015). See also European Commission, 'EU Delivering on the UN 2030 Agenda' (EU Factsheet 2019).
[20] Global Reporting Initiative, UN Global Compact, 'Business Reporting on the Sustainable Development Goals: An Analysis of the Goals and Targets' (February 2019); Carol Adams and others, 'Sustainable

comply with climate change regulations but also to attract responsible investors who increasingly favour sustainable projects and invest their funds accordingly. Digitalization can increase the reliability of sustainability reporting. Nevertheless, we argue that digitalization alone cannot deal with factors such as the multicity, complexity, and lack of comparability of ESG standards and objectives, which can only be addressed through the standardization of the ESG indicators and the methodology for impact reporting.[21] The combination of digitalization and standardization can enhance the credibility, transparency, and efficiency of ESG investing, particularly the issuance of green bonds.[22]

III. Standardization as a Prerequisite for Digitalization of Green Bonds

In 2007-2008, two major supranational issuers, the European Investment Bank (EIB) and the World Bank, paved the path for developing a flourishing new market with their flagship issuances of labelled green bonds.[23] The growth of the green bond market went hand in hand with standardization initiatives. First introduced in 2014 and updated in 2018, ICMA's Green Bond Principles have been the text of reference in this domain.[24] More recently, the EU has developed its own Green Bond Standard,[25] which goes further

Development Goal Disclosure Recommendations' (ACCA, Chartered Accountants ANZ, ICAS, IFAC, IIRC and WBA 2020) 6.

[21] KPMG, 'The Time Has Come: KPMG Survey of Sustainability Reporting 2020' (KPMG 2020) 56 <https://home.kpmg/lu/en/home/insights/2020/11/the-time-has-come-survey-of-sustainability-reporting.html> accessed 16 July 2021; Ian Mackintosh, 'Why Corporate Reporting Standards Are Starting to Converge' (EY Reporting 2019) <https://www.ey.com/en_gl/assurance/why-corporate-reporting-standards-are-starting-to-converge> accessed 16 July 2021.

[22] International Financial Reporting Standards Foundation, 'IFRS Consultation Paper on Sustainability Reporting' (IFRS 2020); Patrick de Cambourg, 'Ensuring the relevance and reliability of non-financial corporate information: an ambition and a competitive advantage for a sustainable Europe' (Report submitted to the French Minister for the Economy and Finance, May 2019).

[23] World Bank, 'Green Bond Impact Report: 10 Years of Green Bonds' (World Bank 2018); European Investment Bank, 'Achievement of the First Green Bond: An Innovative Milestone in Financial Markets' (EIB Climate Awareness Bonds Newsletter 2017) < https://www.eib.org/en/investor_relations/documents/eib-cab-10-years-newsletter.htm> accessed 16 July 2021.

[24] International Capital Markets Association, 'Green Bond Principles: Voluntary Process Guidelines for Issuing Green Bonds' (ICMA 2018); Georgios Pavlidis, 'International Standardisation and Digitalisation of Green Bonds: The Case of Extra-Financial Reporting' (2021) Revue internationale des services financiers / International Journal for Financial Services (forthcoming).

[25] EU Technical Expert Group on Sustainable Finance, 'TEG report on EU green bond standard' (June 2019); Georgios Pavlidis, 'Une nouvelle norme européenne sur les obligations vertes : l'importance de garder l'élan' [2020] 4 Revue Internationale des Services Financiers 11.

than the ICMA Principles, further harmonizes standards, and employs the EU classification system for sustainable activities (EU taxonomy).[26]

To illustrate the interplay between digitalization and standardisation, we examine one of the key components of green bond issuances, extra-financial reporting.[27] In the form of impact reports, extra-financial reporting is not something new in sustainable finance, and it is safe to say that issuers and investors are familiar with the concept.[28] However, as the market for green bonds grows, stakeholders demand high-quality green reporting and, more generally, sustainability reporting. In turn, enhancing the quality, transparency, and comparability in reporting strengthens the credibility of the green bond markets, ostracises deceiving issuers, and ultimately attracts more ESG responsible investors. This is particularly true with large institutional investors, which have been integrating ESG factors into their investment portfolios and rely on verifiable disclosures of ESG risks for making informed decisions.[29] Indeed, the commitment of the issuers to mitigating ESG risks and offering quality reporting to investors may be dictated not only by the prospect of future benefits, such as efficiency gains, green tax credits, image, and reputation gains but also by pure regulatory pressure.[30]

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[26] Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088 [2020] OJ L 198/13. See also the SDG Finance Taxonomy that was adopted by the United Nations Development Programme (UNDP) in 2020; UNDP China, 'Technical Report on SDG Finance Taxonomy' (UNDP 2020); Christoph Nedopil Wang and others, 'Addressing the missing linkage in sustainable finance: the SDG Finance Taxonomy' (2021) Journal of Sustainable Finance & Investment [Latest Articles] https://doi.org/10.1080/20430795.2020.1796101

[27] KPMG International, 'Sustainable Insight: Gearing Up for Green Bonds' (KPMG Global Center of Excellence for Climate Change and Sustainability 2015); Aaron Maltais and Bjorn Nykvist, 'Understanding the role of green bonds in advancing sustainability' (2020) Journal of Sustainable Finance & Investment DOI: 10.1080/20430795.2020.1724864

[28] See International Finance Corporation, 'Green Bond Impact Report Financial Year 2020' (IFC/ World Bank 2020), which was published on the 10th anniversary of IFC's Green Bonds Program; Ans Kolk, 'A decade of sustainability reporting: developments and significance' (2004) 3(1) International Journal of Environment and Sustainable Development 51; Christiano Busco and Elena Sofra, 'The Evolution of Sustainability Reporting: Integrated Reporting and Sustainable Development Challenges' in Paolo Taticchi and Melissa Demartini (eds.), *Corporate Sustainability in Practice* (Springer 2021) 191.

[29] For example, the top fifty asset managers in the world, managing over USD 60tn in assets, have signed onto the UN voluntary sustainability code (United Nations Principles for Responsible Investment) and taken steps to implement it though ESG reporting; see Alicia McElhaney, 'How the World's Largest Asset Managers Are Finally Taking ESG Seriously' *Institutional Investor* (1 March 2021).

[30] Daniel Kinderman, 'Time for a Reality Check: Is Business Willing to Support a Smart Mix of Complementary Regulation in Private Governance' (2016) 35 Policy and Society 29; Emanuele Campiglio and others, 'Climate change challenges for central banks and financial regulators' (2018) 8(6) Nature Climate Change 462.

In this equation, the quality of extra-financial reporting will be a determinant factor for the credibility of the green bonds market. Nevertheless, before exploring digitalization in extra-financial reporting, one has first to define the concept of materiality.[31] Indeed, before digitising green performance data, one must determine which will be the objectives of the reporting, which data are necessary to achieve such objectives, and who the prime audience and stakeholders will be. The "impact" of a green project cannot be measured without first deciding on the appropriate metrics, such as for carbon emissions/footprints or water use. A "one size fits all" approach simply would not do,[32] therefore, digitalization presupposes the development and broad use of standardised metrics for every sector of economic activity. Several organisations, such as the Global Impact Investing Network (GIIN),[33] have proposed their ESG metrics.[34] Nevertheless, we are currently faced with a proliferation of metrics and reporting standards, which often overlap. Moreover, there are "differences in the way the organisations approach materiality, with several organisations focusing on the impact of risks on a company and other organisations focusing on a company's impact on the environment".[35] Manifestly, the success of future digitalization initiatives greatly depends on the development of a commonly agreed definition of materiality, accompanied by standardised impact metrics.

Furthermore, digitalization of extra-financial reporting in green bonds cannot work without a reliable independent verification system by a third party. Responsible investors cannot rely only on the issuer's affirmations or reputation, but their investment

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[31] On materiality in sustainability reporting, see: Daniel Reimsbach and others, 'In the Eyes of the Beholder: Experimental Evidence on the Contested Nature of Materiality in Sustainability Reporting' (2020) 33(4) Organization and Environment 624; Robert Eccles, Michael Krzus and Sydney Ribot, *The Integrated Reporting Movement: Meaning, Momentum, Motives, and Materiality* (Wiley 2014) 135; Riccardo Torelli and others, 'The materiality assessment and stakeholder engagement: A content analysis of sustainability reports' (2020) 27:2 Corporate Social Responsibility and Environmental Management 470; Felix Beske and others, 'Materiality analysis in sustainability and integrated reports' (2020) 11:1 Sustainability Accounting, Management and Policy Journal 162.

[32] Charles Vörösmarty and others, 'Scientifically assess impacts of sustainable investments' (2018) 359:6375 Science 523; Chiara Mio, Marco Fasan and Antonio Costantini, 'Materiality in integrated and sustainability reporting: A paradigm shift?' (2020) 29:1 Business Strategy and the Environment 306.

[33] Global Impact Investing Network, 'Understanding Impact Performance' (GIIN 2020).

[34] Georg Inderst and Fiona Stewart, *Incorporating Environmental, Social and Governance (ESG) Factors into Fixed Income Investment* (World Bank 2018) 7.

[35] IFRS (n 22) 6; Armando Calabrese and others, 'Materiality Analysis in Sustainability Reporting: A Method for Making it Work in Practice' (2017) 6(3) European Journal of Sustainable Development 439.

decisions must rely on reliable third-party verifications. This is crucial for reducing information asymmetries in the markets and discarding "green-washing" practices, namely, issuers attempting to mislead investors by misrepresenting a project as environmentally sound.[36] Two major standardization initiatives, ICMA's Green Bond Principles and the EU's Green Bond Standard, recognise the key role of independent external verification. In practical terms, the issuer must commission an independent third party to review the issuance of the green bond, including the green project's ESG impact. The aim of the review in the pre-issuance phase is to assure alignment of the issuance with a given set of standards, such as the ICMA's Principles, which can lead to a rating or certification.[37] The aim of the review in the post-issuance phase is to assure allocation of proceeds to eligible projects (reports on the use of proceeds) and to report the actual impact of the green project (impact reports), which also may lead to the verification of a certification.[38]

Standardization, combined with digitalization, can also help address another challenge, the labour intensiveness of extra-financial reporting.[39] It has already been mentioned that such reporting in green bonds requires the collection and analysis of voluminous and complex data on environmental impacts. Moreover, reporting is not one-off or sporadic under current market practices, but it takes place periodically throughout the life cycle of the green project, usually annually.[40] The workload and costs of reporting are also increased by national regulations imposing enhanced reporting requirements. This may, in turn, reduce the appeal of green bonds for issuers unless new approaches, such as digitalisation, kick in and manage to alleviate these constraints.

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[36] Maria Jua Bachelet and others, 'The Green Bonds Premium Puzzle: The Role of Issuer Characteristics and Third-Party Verification' (2019) 11(4) Sustainability 1; Addisu Lashitew, 'Corporate uptake of the Sustainable Development Goals: Mere greenwashing or an advent of institutional change?' (2021) Journal of International Business Policy 184.

[37] Among several ratings and certifications, we can mention the Moody's Green Bond Rating, the S&P's Green Evaluation, and the Climate Bonds Certification.

[38] Reports on the use of proceeds are more widely used than reports on environmental impact. In 2019, one in two green bond issuers provided both types of reports, which was particularly true in the context of larger deals ($500 million or more); Climate Bonds Initiative, 'Post-Issuance Reporting in the Green Bond Market' (CBI 2019) 2.

[39] EU Technical Expert Group on Sustainable Finance, 'TEG report on EU green bond standard' (June 2019) 22.

[40] Deloitte, 'Thinking Allowed: The future of corporate reporting' (Deloitte 2016) 8 <https://www2.deloitte.com/content/dam/Deloitte/ch/Documents/audit/ch-en-audit-thinking-allowed-future-corporate-reporting.pdf> accessed 16 July 2021.

To conclude, there is a need to harmonise the rules and standards on green bonds, especially regarding materiality and disclosure requirements. This step is essential before moving forth with digitalization and scaling up fully digitalised green bonds. The EU has recognized this need and made significant progress in putting together its taxonomy for sustainable activities,[41] an EU Green Bonds Standard, alongside other legislative initiatives.[42] Other international initiatives, such as the International Platform on Sustainable Finance, have attempted to coordinate and align national and regional standards, including those on extra-financial reporting. Nevertheless, cooperation among regional standard-setting bodies is important, but the "bottom-up" approach has its limitation and, compared to a "top-down" harmonization initiative, will have more difficulties in ensuring global consistency of standards.[43]

IV. Digitalization Kicks in: The Genesis of Blockchain Bonds

Over the last decade, blockchain, IoT, and AI, which form the so-called "BIA Trinity", have allowed for the development and commercialization of numerous new applications. This trend is here to stay in all areas of social and economic life, including the sustainable finance ecosystem.[44]

Blockchain bonds are one of the innovations that promise to revolutionise international finance, with issuers and investors already exploring the issuance, initial distribution, and trading of such instruments in the bond markets. As their name indicates, blockchain bonds are issued directly onto the blockchain as security tokens.

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[41] Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088 [2020] OJ L 198/13.

[42] See e.g. the revision of the Non-Financial Reporting Directive and the enhancement of non-financial reporting standards; European Financial Reporting Advisory Group, 'Progress report published for project on preparatory work for the elaboration of possible EU non-financial reporting standards' (EFRAG 2020); see also: John Quinn and Barry Connolly, 'The Non-Financial Information Directive: An Assessment of its Impact on Corporate Social Responsibility' (2017) 14 European Company Law 15; David Monciardini, 'The "Coalition of the Unlikely" Driving the EU Regulatory Process of Non-Financial Reporting' (2016) 36 Social and Environmental Accountability Journal 76; Daniel Szabo and Karsten Sorensen, 'New EU Directive on the Disclosure of Non-Financial Information' (2015) 12 European Company and Financial Law Review 307.

[43] IFRS (n 22) 6.

[44] Darius Nassiry, 'The Role of Fintech in Unlocking Green Finance: Policy Insights for Developing Countries' (Asian Development Bank Institute, Working Paper No 883, 2018) 10; Eero Tolo, 'Will Digitalisation Transform the Financial Sector Too?' (Bank of Finland Bulletin 2016).

They continue to exist on the blockchain for operations. From a technical point of view, blockchain bonds rely on open source blockchain technologies, several of which are very advanced and have gained the confidence of market participants. Several examples can better illustrate the design and particularities of blockchain bonds:

First, the World Bank and the Commonwealth Bank of Australia issued a flagship blockchain bond, called Bond-i,[45] issued in 2018. The issuance relied on blockchain technology for the issuance of bonds and their transfer through the instrument's life cycle. More specifically, blockchain was used for the primary issuance of bonds, the bond auction, the bid capture, the bookbuild, and allocation of bonds and subsequent secondary market operations. Another advantage of the project is that it allows for enhanced and real-time visibility of transactions, at least to authorised participants.

Second, an end-to-end blockchain bond was issued in 2019 (USD 20 million, one-year maturity) by the Spanish bank, Banco Santander. The issuance relied on the public open-source Ethereum blockchain;[46] the bonds were securely tokenized in a permissioned manner, and they remained on the blockchain until the end of their maturity. Because of the digitalization and automation of bond issuance, the number of intermediaries involved in the process has been significantly reduced.

Third, the EIB issued its first digital bond in April 2021 (€100 million, 2-year maturity), employing the Ethereum blockchain platform for registration and settlement.[47] The most interesting feature of this issuance is the partnership between the EIB and the Banque de France in the context of the latter's Central Bank Digital Currency (CBDC) experimentation. Indeed, the joint lead managers of the bond issuance will settle the underwriting and pay the issue monies to the EIB using a representation of CBDC on the blockchain, although fiat currency will be used to repay the principal at maturity. The idea to use CBDC in the context of bond issuances had also been tested by Societe Generale, which issued €40 million in covered bonds in May 2020, registering them as

[45] Bond-I stands for "blockchain-operated new debt instrument".
[46] For the press release, see https://www.santander.com/en/press-room/press-releases/santander-launches-the-first-end-to-end-blockchain-bond accessed 16 July 2021.
[47] For the press release, see https://www.eib.org/en/press/all/2021-141-european-investment-bank-eib-issues-its-first-ever-digital-bond-on-a-public-blockchain# accessed 16 July 2021.

security tokens on the blockchain.[48] Additionally, in that case, the issuer was paid in CDBC issued by Banque de France. These two projects have demonstrated that CBDC can be employed for the interbank settlement of financial securities, automating, and simplifying the function of payment systems and market infrastructures.

Furthermore, all these examples illustrate that blockchain technology can be used with success in the phases of bond issuance, initial distribution, transfer of ownership, payment, and settlement.[49] In any case, a designated entity (tokenization agent) is needed to register the bonds on the blockchain and act as the custodian of the cryptographic keys. Investing in such instruments takes place following the model of on-chain delivery-versus-payment. The bonds, the coupons, and the cash used to complete the investment can be represented digitally as tokens. Both in the initial issuance and the aftermarket, blockchain technology ensures (i) an auditable and immutable transaction record; (ii) real-time reporting and instant communication between investors and issuers;[50] (iii) direct holding of assets, which remains secure even in the absence of custodians; (iv) consistency of data across bond market actors, without the need of data reconciliation. Financial transactions can take place on the blockchain more efficiently, because they are recorded and validated in a distributed and immutable database without the need for a trusted custodians and intermediaries, thus reducing associated transaction costs.

In the same way, the disclosure of green data in non-financial reporting increases transparency, reduces information asymmetry and prevents "green-washing", namely, the practice of misrepresenting a project as environmentally sound. In the absence of credible non-financial reporting, it is difficult for stakeholders other than the issuer to obtain factual information on the performance of the green project and the proper use of green bond proceeds. Issuers of green bonds already resort to the services of external reviewers and certification bodies in order to mitigate information asymmetries and

[48] For the press release, see https://www.societegenerale.com/sites/default/files/200023_pr_societe_generale_performs_the_first_financial_transaction_settled_with_a_central_bank_digital_currency.pdf accessed 16 July 2021.
[49] Richard Cohen and others, 'Automation and Blockchain in Securities Issuances' [2018] Butterworths Journal of International Banking and Financial Law 144.
[50] HSBC, 'Sustainable Digital Finance Alliance, Blockchain: Gateway for Sustainability-linked Bonds' (HSBC Centre of Sustainable Finance 2019) 9 <https://www.sustainablefinance.hsbc.com/mobilising-finance/blockchain-gateway-for-sustainability-linked-bonds> accessed 16 July 2021.

protect responsible investors and ultimately the market itself against "green-washing". Non-financial reporting is a significant data service that the issuer needs to provide to investors and to the financial market authorities, with external reviewers ensuring data accuracy. As will be discussed, IoT, AI and blockchain can further improve the data accuracy and the efficiency of non-financial reporting in green bonds; they can reduce costs, automate data harvesting and analysis and bring credible green performance data to investors on real-time.

V. A New Breed of Fully Digitalised Green Bonds?

Could the model of blockchain bonds be transposed into the specific field of green finance? A first attempt took place in February 2019 with a bond issuance (€35 million, six-year term) by the BBVA Group.[51] The green bond was a structured instrument, the return of which was linked to the evolution of the swap rate for euros. The transaction was a private placement, the investor being a global insurance company, while the proceeds were earmarked to finance eligible green projects. In this regard, the issuance obtained a green certification by an independent third party. Blockchain technology and, more specifically, the blockchain platform that BBVA internally developed, was used to negotiate the conditions of the issuance (structure and prices). The issuance was surely innovative in this regard, but one must consider that this was simply a private placement, while blockchain was not used in other phases of the bond's life cycle, consistent with the World Bank's Bond-i issuance.

The next big challenge will be creating a new breed of fully digitalised green bonds, using blockchain from its issuance until the reporting phase,[52] which in the case of green bonds covers both the use of proceeds and the proof of impact. The World Bank's Bond-i has already used blockchain in most phases of the bond's life cycle (primary issuance,

[51] BBVA Group, 'BBVA issues the first blockchain-supported structured green bond for MAPFRE' (BBVA Press Release, 19 February 2019) <https://www.bbva.com/en/sustainability/bbva-issues-the-first-blockchain-supported-structured-green-bond-for-mapfre/> accessed 16 July 2021.

[52] Organization for Economic Co-operation and Development, 'The Tokenisation of Assets and Potential Implications for Financial Markets' [2020] OECD Blockchain Policy Series 24 <https://www.oecd.org/finance/The-Tokenisation-of-Assets-and-Potential-Implications-for-Financial-Markets.htm> accessed 16 July 2021.

bond auction, bond allocation, payment and settlement, transfers in secondary market), but digitalization has not been applied in the reporting phase (tokenised proof of impact), which appears at first like a daunting task. Nevertheless, there have been successful uses of digitalization for green data reporting, which could be implemented and scaled up in the green bond markets. For example, a successful initiative of UNDP in Lebanon aimed to reforest depleted forests (CedarCoin initiative).[53]

Scaling up digital green reporting would implicate collecting, uploading on the blockchain, and ultimately delivering green data to the digital wallets of investors in real-time.[54] Data that are relevant to a given sustainable project would need to be collected using sensors. Given the huge volume of datasets and the lack of well-structured data formats, AI analytics will have to be employed to be used to organise such data volumes, make sense out of them, and compile impact reports. For example, the Global Mangrove Trust supports the planting of mangrove trees in the Bay of Bengal and uses blockchain, satellite telemetry, and AI to allow sponsors to verify that the trees they have sponsored have indeed been planted and how the forest is growing year after year.[55]

In this paradigm shift towards automated reporting, digitalization will allow us "to harvest recognised metrics, codified as data tokens that communicate in real-time to investors and build a shared asset history on the ledger [...] accessible to multiple stakeholders".[56] Not only will this model enhance the reliability and the traceability of the green data, but it will also slash down the average cost of reporting. It has been estimated that the cost of IoT devices, data gathering, aggregation, and reporting can be thus reduced by up to ten times in the lifecycle of a green project.[57] Fortuitously, the major economic sectors that employ IoT and already harvest data automatically (transport,

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[53] CedarCoins are digital tokens that allow the owner to finance the planting of cedars in Lebanon. The transaction includes a "proof of planting", which is also in use in other reforestation initiatives worldwide; United Nations Development Programme, 'Adopting a cedar tree brings diaspora money home' (UNDP Lebanon 2019) <https://www.undp.org/blogs/adopting-cedar-tree-brings-diaspora-money-home> accessed 16 July 2021.

[54] Wanli Chen and Qianxia Wang, 'The Role of Blockchain for the European Bond Market' (Frankfurt School Blockchain Center 2020) 11; see also Stockholm Environment Institute, 'The Green Assets Wallet: First Blockchain for Green Bond Impact Data' (SEI 2019) <https://www.sei.org/about-sei/press-room/first-blockchain-for-green-bonds/ > accessed 16 July 2021.

[55] See https://globalmangrove.org/news. A similar innovative application is TreeCoin, a blockchain-based digital currency used for reforestation and timber cultivation.

[56] HSBC (n 50) 6.

[57] ibid 17.

energy, and water)[58] are the ones where the issuance of green bonds and climate-aligned bonds is on the rise. This would render more feasible the transition towards fully digitalised green bonds, which also cover extra-financial reporting.

Two questions are raised in this context. The first question is who will own Big green data and who will have access to it. Even if IoT sensors are used to harvest data and AI is employed to analyze data and correct eventual errors, the ultimate responsible for data accuracy is the entity that issues the green bond. Under international standards, such as the ICMA Principles, reporting green data to investors is a key task of the issuer, who has to ensure that the relevant technology (sensors, AI), ESG metrics and ESG reporting procedures are reliable and do not mislead investors. The second question is whether environmental data can be transferred easily due to national law such as data localization, security law and other barriers, if human activities are involved. Indeed, national legislation may impose to the issuer of the green bond the obligation to keep data within the jurisdiction it originated from, thus preventing the transfer and processing of data in another jurisdiction. In some sectors, such as healthcare, banking and payment systems, there may be stricter requirements for processing data abroad, discouraging companies from doing so. In the case of green investments, the disclosure of data related to the asset ownership and the performance of the asset entails risks, such as privacy breaches and harm of national security. Green performance data, such as the performance of strategically important renewable energy projects, may fall within the scope of data localization laws, which will definitely hinder international issuances of green bonds in an increasing number of jurisdictions.

Moreover, the success of a transition towards digitalised green bonds depends greatly on the definition of the exact metrics that will be used for automated reporting. It must be clear to all stakeholders which specific data will be collected, analysed, and reported. This is a prerequisite for ultimately generating impact indexes for a green project or several green projects. The impact indexes will have to combine several

[58] Sandro Nizetic and others, 'Internet of Things (IoT): Opportunities, issues and challenges towards a smart and sustainable future' (2020) 274 Journal of Cleaner Production 122877; Kyoochun Lee, 'The Internet of Things (IoT): Applications, investments, and challenges for enterprises' (2015) 58(4) Business Horizons 431; Jayavardhana Gubbi and others, 'Internet of Things: a vision, architectural elements, and future directions' (2013) 29(7) Future Generation Computer Systems 1645.

indicators (energy generated, energy saved, air quality, CO2 emissions, etc.) collected from multiple monitoring points over specified times. Furthermore, there are proposals in favour of the so-called "pull" reporting systems, where performance data is delivered to the "digital wallet" of investors, regulators, or other stakeholders with permissions, from which the user can choose the data to pull out,[59] provided that the aforementioned national data localization laws do not require otherwise.

VI. Concluding Remarks

The use of blockchain, IoT, and AI can revolutionize green finance, alleviate unnecessary costs and burdens, and enhance transparency and credibility in the green bond market. Digitalization can benefit the issuance, initial distribution, trading, and reporting of green bonds. It can also pave the way for follow-on innovations, facilitating fragmented ownership of green assets, alongside the aggregation of several green projects and assets into one bond.[60] Businesses and regulators already explore interesting new ideas, such as the development of blockchain-based bond exchanges, which allow for fractional ownership of bonds. This is the case of the BondbloX Bond Exchange (BBX), which obtained authorization from the Monetary Authority of Singapore in August 2020, and the Joinvest platform, which was approved by the Financial Supervisory Commission of Taiwan to function in the regulatory sandbox for one year. In the same logic, the Philippines Bureau of the Treasury has developed and launched a mobile application to allow small retail investors to purchase treasury bonds, replacing banks in financial intermediation. Even more cross-cutting innovations are underway, such as the project of the Singapore Exchange to build the regions first "end-to-end digital infrastructure in the fixed income space" and to "streamline the listing, straight-through processing and settlement of bonds and activities in bond lifecycle management".[61]

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[59] Eloy Barrantes and Henning Zülch, 'Digitaler Geschäftsbericht als Hidden Champion – Vom Pull- zum Push-Reporting' (2019) 19 Zeitschrift für internationale und kapitalmarktorientierte Rechnungslegung 156; HSBC (n 50) 20.

[60] Climate Bonds Initiative, 'Scaling up Green Bond Markets for Sustainable Development' (CBI Consultation Paper 2015) 17 <https://www.climatebonds.net/resources/publications/scaling-green-bond-markets-sustainable-development> accessed 16 July 2021; HSBC (n 50) 5.

[61] For the press release, see https://www.sgx.com/media-centre/20210129-sgx-and-temasek-jv-ties-covalent-build-end-end-digital-infrastructure accessed 16 July 2021.

In this rapidly evolving digital ecosystem, it is difficult to ensure regulatory clarity on the use of blockchain in securities issuances. For this reason, standardization initiatives, such as the ICMA Principles and the EU Green Bond Standards, need to address digitalization specifically to facilitate its adoption in green bonds markets. This should include developing common standards for the digitalization of extra-financial reporting (use of proceeds reports and impact reports). Indeed, new-fashioned international standards are needed for a new generation of financial instruments, such as blockchain green bonds. Furthermore, combining digitalization with international standardization will further allow the scaling of green bond markets to meet the growing demand. Although green bonds represent 2% of the global bonds market, the demand and offer in sustainable bonds and blockchain-enabled instruments are expected to grow exponentially in the aftermath of the COVID19 crisis, supported by government policies, international and regional initiatives, particularly at the EU level (Green Deal, Green Bond Standard, and Digital Finance Package). Therefore, the circumstances are auspicious for experimenting with the development of fully digitalised green bonds and sustainable digital finance in general, which can increase transparency, accelerate clearing and settlement, simplify securities trading, and facilitate reporting to investors, and for supervisory purposes.